The *Journal of Cotton Science 11:52–59 (2007)*
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ENGINEERING AND GINNING

Weed Suppression Potential of Dry Applied Mulches Used in Bedding Plant Applications: Processed Cotton Gin By-products Versus Conventional Wood

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ABSTRACT

One of the potential uses of processed cotton gin by-products (gin waste or gin trash) is as a mulch in bedding plant applications. A value-added technique known as the COBY Process was used to produce three mulches from different types of gin waste (Arizona picker trash, ground Texas stripper trash, and Texas stripper trash). This study compared the effectiveness of the COBY products with the raw material from which they were produced and with a conventional wood mulch on weed suppression. Mulches were applied at 1.47, 2.94, and 4.39 kg/m^2. The COBY mulches performed equal to or better than the raw gin waste or the wood mulch in suppressing weeds; however, ageratums planted in two of the COBY treatments exhibited signs of reduced plant growth. The reduced plant growth appeared to be due to high soluble salt concentrations. The increase in soluble salts of the COBY product could be attributed to the water and dye solutions used in the processing. The COBY process can be used to produce a mulch that is effective at suppressing weed growth. The process needs refinement to minimize any negative characteristics or properties for COBY mulch applications where salt sensitive bedding plants are being grown.

The use of cotton gin by-products (CGB), also known as gin trash or gin waste, as a soil amendment has been the focus of various research efforts over the past several decades (Box and Walker, 1959; Edwads and Walker, 1997; Huitink, 2002). Studies evaluating the use of CGB as a soil amendment have included treating soil with the raw material (Fryrear and Koshi, 1974) or composted CGB (Seiber et al., 1982). Using raw CGB as a soil amendment could result in weed infestation (Fryrear, 1981) because of the weed seed present in the raw material. Composting CGB destroys weed seeds (Hills et al., 1981), but composting can be costly, labor intensive, and time consuming (3 to 7 wk) (Alberson and Hurst, 1964; Hills et al., 1981; Hills, 1982).

The COBY process developed at the USDA-ARS, Cotton Production and Processing Research Unit in Lubbock, Texas, is a method of adding value to waste by-products from cotton processing facilities (Holt and Laird, 2002). One of the products from the COBY process is bedding mulch for use in flowerbeds or other landscaping applications. When the COBY process is used to produce mulch, an extruder is used to aid in the sterilization of the raw material. The raw material is pressure-cooked at temperatures around 110 °C and ground within 20 to 30 s.

The objectives of this study were 1) to compare COBY treated cotton gin by-products versus the raw material for their effectiveness at suppressing weeds and 2) to compare conventional wood chip mulch to COBY mulches for effectiveness in weed suppression.

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MATERIALS AND METHODS

Treatments, plot layout, and mulch application. The experimental treatments in this study were seven mulches applied at three application rates. The seven mulches were as follows: 1) CGB from Arizona (Arizona picker), 2) CGB from Texas High Plains (Texas stripper), 3) ground CGB from Texas High Plains (ground Texas stripper), 4) COBY Green, 5) COBY Red, 6) COBY Yellow, and 7) conventional hardwood chip mulch (wood). The seven mulches were applied at 1.47, 2.94, and 4.39 kg/m^2. The COBY mulches were colored for ease of identification only. Any influence color may have had on the findings presented is addressed in the Results and Discussion section.

All treatments were evaluated at the Summit Seed, Inc., facility in Manteno, Illinois. Experiments were established on 15 May 2003 and evaluated for 8 wk. Prior to establishment, the flowerbed plots were treated with glyphosate (500 mL/L) to kill existing vegetation. After 10 d, the soil was tilled to a depth of 10.5 cm with a roto-tiller. The ground was graded smooth to ensure a firm soil for establishing ornamental plants. The plot size for each treatment was 1.52 m x 1.52 m. The mulch treatments were applied uniformly by hand. After applying the mulch treatments, ageratum (*Ageratum houstonianum* cultivar Hawaiian Blue), also known as floss flower, were transplanted into the plots. The plants were about 10 cm tall and 6-wk-old. The ageratums were established on 0.31-m centers (16 plants per plot) by digging a shallow hole (7.6 cm deep) and gently firming the soil around the stem of the plants. The mulch treatments were moved aside prior to planting the ageratum, and then the mulch was relocated around the base of each plant. Immediately following the planting of the ageratums, the entire experimental area was watered to field capacity. All planting beds received an average of 2.5 cm of water per week for the 8-wk study period.

Data recording and monitoring. Once all the mulches were applied to the plots and the ageratums planted, a digital image was taken of each treatment (mulch/application rate combination). To ensure the lighting was the same for each image, an enclosed square structure made of plastic piping and black plastic was built and placed over each plot. The size of the plastic structure was 1.5 m wide by 1.5 m long by 1.5 m high. The images were taken for digital analysis to determine the initial coverage factor (C-factor) associated with the different treatments.

Soil temperature and number of weeds were measured weekly. Soil temperature was measured at a depth of 8 cm at three locations in each plot using a digital probe thermometer (Chaney Instrument Company; Lake Geneva, WI). The number of weeds were counted within each plot. Weed count was repeated twice in each plot each week to verify accuracy.

Soil moisture was measured at a depth of 8 cm in three locations of each plot for at least 4 d of each week. The moisture readings were performed using a Field Scout TDR 300 soil moisture meter (Spectrum Technologies, Inc.; Plainfield, IL). The same technician collected data each week.

In addition to the weekly data collection, one soil sample from one of the treatment plots (rate and mulch) and one mulch sample were sent for analyses prior to the planting the ageratums. The soil samples were analyzed for nutrients and micro-nutrients (Brown, 1998). The mulch samples were analyzed for pH (Warncke, 1986), organic matter (Nelson and Sommers, 1996), soluble salts (Warncke, 1986), total organic carbon (USEPA, 1986), N, P, K, Ca, Mg, and dry matter (USCC, 2003).

Image analysis. The digital coverage images were analyzed by first obtaining a 3-D scatter graph of the images, where the x, y, and z positions were assigned based on the class = {ground, mulch, plants}. In some cases, the 3-D scatter-plot revealed a clearly separable set of dividing planes that could be used as a set of linear discriminant functions. Therefore, for these images, the dividing planes were determined directly from the 3-D scatter plots. In other cases when the classes were not clearly separable, Bayesian pattern recognition techniques were utilized to determine the set of linear discriminant functions.

To use a Bayesian classifier, the covariance, mean, and population size statistics were identified. From these basic statistics, conditional probabilities were derived which formed the basis for the Baye's Classifier. To obtain the statistics for each of the images in the study, two individuals took each image and classified a subset of the pixels from each of the three classes. From these training sets, the mean color and covariance of the colors for each class were determined. To estimate the size of the population from each class, the same two individuals visually estimated the coverage to the nearest 5%.

Mulches evaluated. The raw material used for the COBY Yellow and COBY Green products was acquired from two commercial gins. The COBY Red, which included motes, was obtained from the USDA-ARS Cotton Ginning Laboratory in Lubbock, Texas. The picker waste (COBY Yellow) was obtained from a gin in Arizona. The stripper waste (COBY Green) that had been ground through a tub grinder was obtained from a gin near the Ginning Laboratory. All the gin by-products were processed using the COBY Process at the USDA-ARS, Cotton Production and Processing Research Unit in Lubbock, Texas.

Figure 1 shows a schematic of the COBY process. The raw material was loaded using a pneumatic conveyer into a live-bottom bulk-feed bin with five, 22.9-cm augers. Upon exiting the feed bin, the gin by-products were sprayed with either a gelatinized starch solution containing a red, green, or a yellow dye, depending on the raw material being processed. The starch was added to reduce abrasion from the raw material on the processing equipment. The sprayed material was conveyed in twin 30.5-cm cut-and-fold mixing augers (blending conveyor) to a side-feeder that force-fed the by-product slurry mix into an Insta-Pro model 2000 extruder (Insta-Pro International; Des Moines, IA). The extruded product was conveyed to a belt dryer and dried at 135 °C then stored in nylon tote bags.

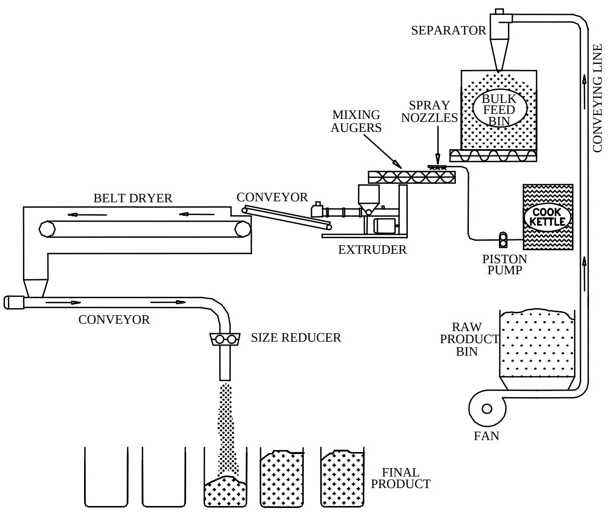

Figure 1. Schematic of the process used to produce the COBY mulch.

The gelatinized starch slurry consisted of 0.453 kg of starch to every 3.78 L of water in the cook kettle. The starch slurry was applied via a piston pump driven by a 0.56 kW DC motor regulated by a closed-loop control system. The control system was comprised of a flowmeter with a 0-10 VDC output signal to the DC drive regulating the speed of the motor driving the starch pump. The amount of starch added to the by-products was 5% by weight of the products (i.e. 6.79 kg/min of by-products had 0.34 kg/min of starch added).

Experimental design and analysis. There were two sets of comparisons performed consisting of seven mulches (COBY green, COBY yellow, COBY red, Texas stripper trash, ground Texas stripper trash, Arizona picker trash, and a conventional wood mulch) at three application rates (1.47, 2.94, and 4.39 kg/m^2). The experiment was arranged using a completely randomized design with three replications of mulch and rate. The first comparison consisted of the raw gin waste versus the COBY mulches, where specific comparisons were performed between the raw parent material and the COBY mulch from which it was produced. The second analysis consisted of pair-wise comparisons of the COBY and wood mulches. The response variable, number of weeds counted, was modeled with Poisson regression using the PROC GLIMMIX procedure in SAS (Littell et. al., 2006). The GLIMMIX procedure was used since it makes available some enhanced features for computing output statistics compared with PROC MIXED (version 9.1.3; SAS Institute; Cary, NC). Tukey's Honestly Significant Difference (HSD) was used for multiple comparison adjustment. Since the coverage factor (C-factor) was evaluated only once at the beginning of the study, standard analysis of variance techniques were used to analyze the data using the Ryan-Einot-Gaberiel-Welsch multiple range test at the 95% confidence interval.

RESULTS AND DISCUSSION

Table 1 shows the results of three specific comparisons of the raw gin waste material to the COBY treated gin waste. The data for the Texas stripper and ground Texas stripper mulches showed increasing weed counts at the lower application rates. A similar result was observed for the derived COBY mulches. The COBY Green and Red mulch were not significantly different from their parent material at a given application rate. For the Arizona Picker, weed count increased as the application rate increased, which was opposite of what was expected. For the COBY Yellow and the other gin waste and COBY mulches, as the application rate increased the weed count decreased. The highest application rate of Arizona picker (4.39 kg/m^2) had significantly more weeds (66.7) than did the lowest application rate of COBY Yellow (1.47 kg/m^2), which had an average weed count of 42. Some of the weeds growing in the Arizona picker plots are not commonly encountered in Illinois and most likely originated from the mulch. The increase in weeds with the Arizona picker mulch gives credence to the theory that raw CGB need to be sterilized to kill weed seeds. The amount of weed seeds in CGB can vary greatly depending on how producers control weeds in their fields. The uncertainty of weed seeds in the raw material is one of the primary concerns of producers applying the raw material back to the land (Thomasson, 1990).

Table 2 shows multiple comparison results of the weed count data for the wood and COBY mulches. Weed count data show the wood mulch at the mid-range application rate (2.94 kg/m^2) to be significantly higher than COBY Green and Red at the same application rate. There were only two mulches that had significantly higher weed counts than the highest application rate of wood, COBY Yellow (1.47 kg/m^2) and wood (2.94 kg/m^2). For the wood, COBY Yellow, and COBY Green mulches, there was no significant reduction in the number of weeds as application rate increased from 1.47 kg/m^2 to 2.94 kg/m^2. COBY Red was the only mulch that had significantly fewer weeds for the mid-range application rate (22) compared with the weed count at the lowest application rate (38.3). In regards to weed count differences between the 2.94 kg/m^2 and 4.39 kg/m^2 application rates, COBY Yellow and wood were the only two mulch types with significant differences. For both of these mulches, the 2.94 kg/m^2 application rate had a higher weed count than the 4.39 kg/m^2 rate.

Table 1. Least squares means of weed counts at 8 wk for the treatment by application rate of COBY treated gin by-products versus the raw material used to produce the respective COBY material

Raw material[z]	Treatment	Rate (kg/m^2)	Weed count[y]
Arizona picker			
	Arizona Picker	1.47	56.3 ab
	Arizona Picker	2.94	57.0 ab
	Arizona Picker	4.39	66.7 a
	COBY Yellow	1.47	42.0 bc
	COBY Yellow	2.94	29.0 cd
	COBY Yellow	4.39	12.0 d
Texas stripper			
	Texas Stripper	1.47	39.0 a
	Texas Stripper	2.94	21.3 bc
	Texas Stripper	4.39	13.3 c
	COBY Green	1.47	32.3 ab
	COBY Green	2.94	21.3 bc
	COBY Green	4.39	10.3 c
Ground Texas stripper			
	Ground Texas Stripper	1.47	33.3 ab
	Ground Texas Stripper	2.94	25.3 bc
	Ground Texas Stripper	4.39	9.7 e
	COBY Red	1.47	38.3 a
	COBY Red	2.94	22.0 cd
	COBY Red	4.39	12.0 de

[y] Standard error for Arizona picker versus COBY Yellow comparison = 5.46; Standard error for Texas Stripper versus COBY Green comparison = 4.27; Standard error for Ground Texas Stripper versus COBY Red comparison = 3.24.

[z] Means within a column for a given raw material followed by the same letter are not significantly different at the 95% confidence limit according to Tukey's HSD.

Table 2. Least squares means of weed counts at 8 wk for treatment by application rate of COBY mulches and conventional wood mulch

Treatment	Rate (kg/m^2)	Weed count[z]
COBY Yellow	1.47	42.0 a
COBY Yellow	2.94	29.0 abc
COBY Yellow	4.39	12.0 d
COBY Green	1.47	32.3 abc
COBY Green	2.94	21.3 cd
COBY Green	4.39	10.3 d
COBY Red	1.47	38.3 ab
COBY Red	2.94	22.0 cd
COBY Red	4.39	12.0 d
Wood	1.47	37.3 ab
Wood	2.94	39.3 a
Wood	4.39	24.3 bcd

[z] Means within the same column for a given raw material followed by the same letter are not significantly different at the 95% confidence limit according to Tukey's HSD. Standard error for comparisons = 3.99.

Table 3 shows differences in the coverage factor variable based on mulch type and application rate. The coverage factor for wood was significantly less than ground Texas stripper, COBY Red, and COBY Green. The other mulches did not have coverage that was significantly different from each other. Wood had the lowest average coverage at 82%, while COBY Green had the highest average at 95%. The high and mid-range application rates did not have significantly different coverage factors; however, their coverage factors were significantly higher than the lowest application rate, 1.47 kg/m^2.

Analytical results of the raw gin by-products and mulches are shown in Table 4. These are based on one sample from each mulch. The data show the COBY mulches and the raw gin by-products had higher nitrogen, phosphorous, potassium, calcium, and magnesium concentrations than the wood mulch. The pH for all the mulches and gin wastes was around 6.0. The lowest pH was seen in the COBY Red (5.9) and the highest pH was seen in both COBY Yellow and Arizona picker (6.5). Percentage organic matter was lowest for Arizona picker (75.2) and highest for the wood mulch (93.8). Two of the COBY mulches had an increase in organic matter over their parent material ranging from 2.6% (Arizona picker versus COBY Yellow) to 7.3% (ground Texas stripper versus COBY Red). This increase in organic matter appears to be the result of the additional processing that removed sand/soil and other inorganics. The carbon-to-nitrogen ratio (C:N) of all the mulches, except wood, ranged from 33 to 45. The ideal ratio for decomposition of organic material is around 30 (Richard and Trautmann, 2006; UCCE, 2006). Wood C:N was 130, which was within the expected range of 100 to 500 (Rosales et al., 1997).

Table 3. Mean coverage factor for the mulches and application rates

Variable	Mean coverage factor[z]
Mulch	
Arizona Picker	90 ab
COBY Green	95 a
COBY Red	94 a
COBY Yellow	90 ab
Ground Texas Stripper	94 a
Texas Stripper	93 ab
Wood	82 b
Application rate (kg/m^2)	
1.47	80 b
2.94	95 a
4.39	98 a
Analysis of variance	
Source	***P*-value**
Treatment	0.007
Rate	<0.001
Treatment*rate	0.442

[z] Means within the same column for either mulch or application rate followed by the same letter are not significantly different at the 95% confidence limit according to Ryan-Einot-Gaberiel-Welsch multiple range test.

Additional data recorded during the study included soil moisture and temperature. Figures 2 and 3 illustrate the trends of soil moisture and temperature, respectively, over the 8-wk study for two of the seven mulches evaluated. The data in Figures 2 and 3 are representative of all treatments over the 8-wk period. Two mulches shown in Figures 2 and 3 are for the 2.94 kg/m^2 application rate and were selected randomly to illustrate the similarity in the soil moisture and temperature data. In Figure 2, soil moisture starts to rise in week six and continues to rise until the end of the study. This increase in soil moisture corresponds to rain events toward the end of week six in which 5.5 cm of natural rainfall occurred on the plots. During the last two weeks, the plots received 2.4- and 2.9-cm rainfalls, which were evenly distributed over the time period. Figure 3 shows a logical trend of soil temperature rising over the study period, mid-May to early July. The drop in soil temperature from week six to seven corresponds to the rains received at the end of week six. The soil moisture and temperature data were recorded in the event that this information was needed to support or explain the weed count data; however, the data for these two variables did not indicate significant differences within or between any of the wood, cotton based, and/or COBY mulches.

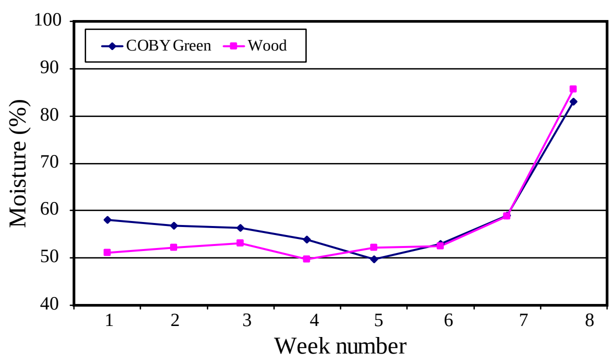

Figure 2. Soil moisture content over the 8 wk evaluation period for one plot of COBY Green and wood mulch applied at the 2.93 kg/m^2.

Table 4. Analytical results of the mulches evaluated in this study

Mulch[z]	Nitrate nitrogen (ppm)	Phosphorous (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	pH (SU)	Organic matter (%)	C/N ratio (%)
Arizona Picker	60	96	1769	948	262	6.5	75.2	33
COBY Green	40	109	1749	268	153	6.4	83.6	37
COBY Red	56	106	2131	608	243	5.9	89.4	39
COBY Yellow	59	88	1990	1048	324	6.5	77.8	33
Ground Texas Stripper	34	119	1578	282	138	6.4	82.1	34
Texas Stripper	45	89	1658	378	144	6.0	83.5	45
Wood	5	12	144	117	46	6.0	93.8	130

[z] Only one sample was analyzed for each mulch.

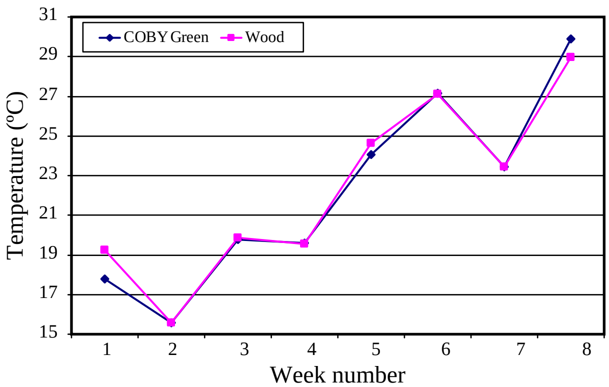

Figure 3. Soil temperature over the 8 wk evaluation period for one plot of COBY Green and wood mulch applied at the 2.93 kg/m^2.

The affects of mulch color on plant health, growth, and yield have been extensively studied (Orzolek and Lamont, Jr., 2000; Alam and Zimmerman, 2001; Pons, 2003; Taber and Lawson, 2003; Kasperbauer and Loughrin, 2004; Lacascio et al., 2005; Anttonen et. al., 2006). Some of the studies report no significant influence of mulch color, while others report a significant influence. Overall, most of the studies indicate some influence on yield, pest response, soil temperature, soil moisture, plant health, and/or various other aspects of plant growth because of mulch color. In this study, plant and/or weed health, yield, and/or robustness were not evaluated, only the number of weeds (count). The weeds were counted regardless of size. If the color of mulch was significant to the findings presented, it is believed the soil moisture and/or temperature would have been significantly different based on mulch type (color). Neither soil moisture nor temperature, however, was significantly different within or between mulches.

None of the tables and/or figures show data for the ageratums planted in each plot. Since this was intended to be an evaluation of COBY processed gin waste as a mulch for weed suppression and not a horticultural study on plant health resulting from mulch types, the ageratums were planted as visual indicators to see if there was a problem with any of the mulches and/or plots. The visual observations of the plots indicated that some of the ageratums in the COBY plots did not appear as healthy as those in the conventional wood mulch plots. Further investigation showed that the soluble salt content of the mulches (Fig. 4) was high to very high (Warncke, 1998). To determine why the COBY mulches had high soluble salt contents, the water and dyes used in process were analyzed for soluble salts (Carrow and Duncan, 1998). The water was analyzed individually and in solution with the starch and dyes used in the process. The water and starch slurry was analyzed at the ratio of 0.453 kg starch to 3.78 L water, while the dyes were analyzed as 2% by volume dilutions. The results (Fig. 5) show that the water, water plus starch, red dye, and green dye solutions contained salinities in the range (medium) where sensitive plants may show salt stress (Carrow and Duncan, 1998). The yellow dye solution was in the range where salinity would adversely affect most plants.

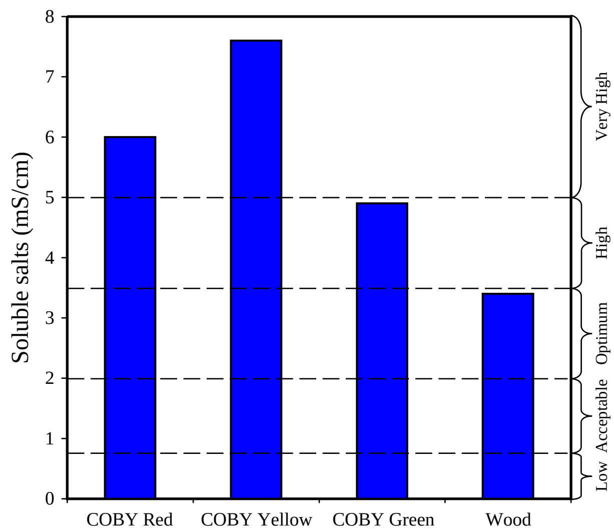

Figure 4. Soluble salt concentration using saturated media extraction by water method for the mulches evaluated. The levels, low to very high, are described by Warncke (1998).

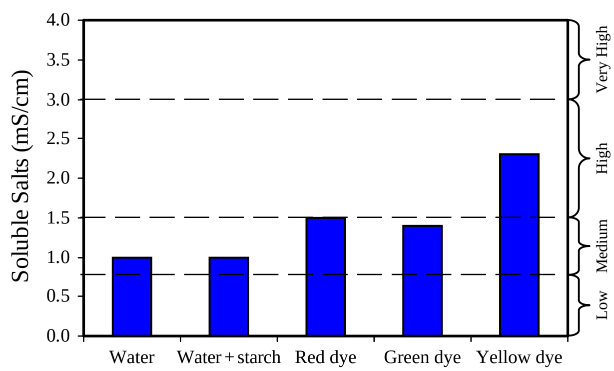

Figure 5. Soluble salt concentrations for the water, water plus starch, and water plus dye mixtures used in the processing of the cotton gin by-products. Levels, low to very high, are described by Carrow and Duncan (1998).

SUMMARY AND CONCLUSIONS

This study that was designed to compare 1) COBY treated cotton gin by-products versus the raw material for their effectiveness at suppressing weeds and 2) compare conventional wood chip mulch to COBY mulches for weed suppression effectiveness at three application rates (1.47, 2.94, and 4.39 kg/m^2). For the first objective, specific comparisons of the raw gin waste material to the derived COBY mulch were performed. For all but one raw gin waste (Arizona picker), the raw material did not result in significantly different weed counts than its respective COBY mulch. For Arizona picker, the weed count was significantly higher than the COBY mulch. The primary reason is believed to be the weed seed in the raw material. Likewise, as the application rate of Arizona picker increased, the weed count increased. These results illustrate the importance of sterilizing cotton gin by-products to kill weed seeds, if they are to be marketed commercially as mulch.

Analyses of the mulches revealed the COBY had soluble salt concentrations that were high enough to either reduce plant growth and vigor or cause severe salt injury symptoms. Upon further analysis of the components used in the manufacture of the mulches (i.e. water, starch, and dye mixtures), the soluble salt concentrations of the yellow dye and water mixture was shown to be in the "high" classification range. The situation occurring with the soluble salt concentration emphasizes the importance of understanding how process inputs and ingredients can influence the final product being produced.

ACKNOWLEDGEMENTS

The partial support of this research by Cotton Incorporated and Summit Seed, Inc. is gratefully acknowledged.

DISCLAIMER

Mention of product or trade names does not constitute an endorsement by the USDA-ARS over other comparable products. Products or trade names are listed for reference only.

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